Development of harvest control rules for Atlantic herring:

An application of MSE to account for herring's role in the ecosystem

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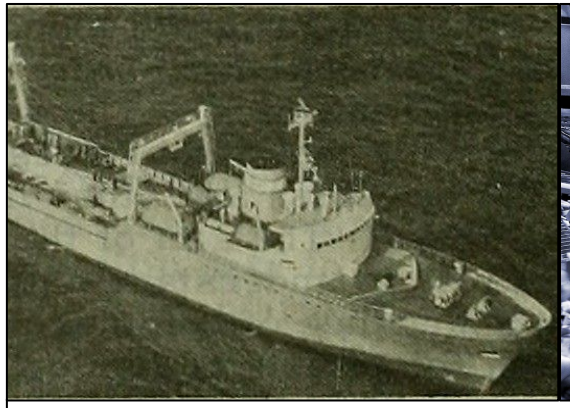
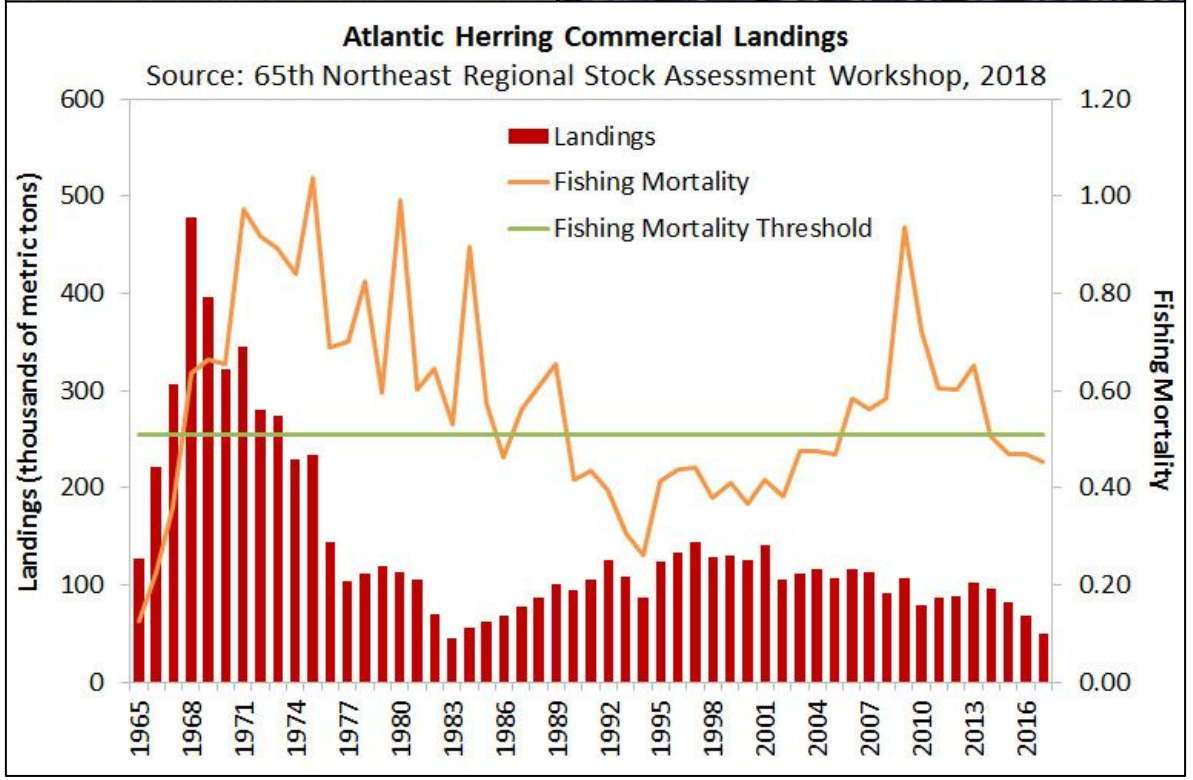
Fishery Applications Consulting Team
Tying science to management for sustainable solutions

New England Fishery Management Council

Herring's History in the Northwest Atlantic

- Centuries-long harvest history
  - Coastal catch before 1900s
  - Offshore fishery post-WWII
- Peak catch in late-1960s, prior to US EEZ, resulted in stock collapse
  - Georges Bank spawning component
- Rebuilt herring stock by mid-1990s
  - Federal investment to capitalize on the growing resource
  - Introduction of mid-water trawl gear
- Initial concerns about depletion and ecosystem impacts by late-1990s
  - Impacts to other commercial and recreational fisheries, predator species

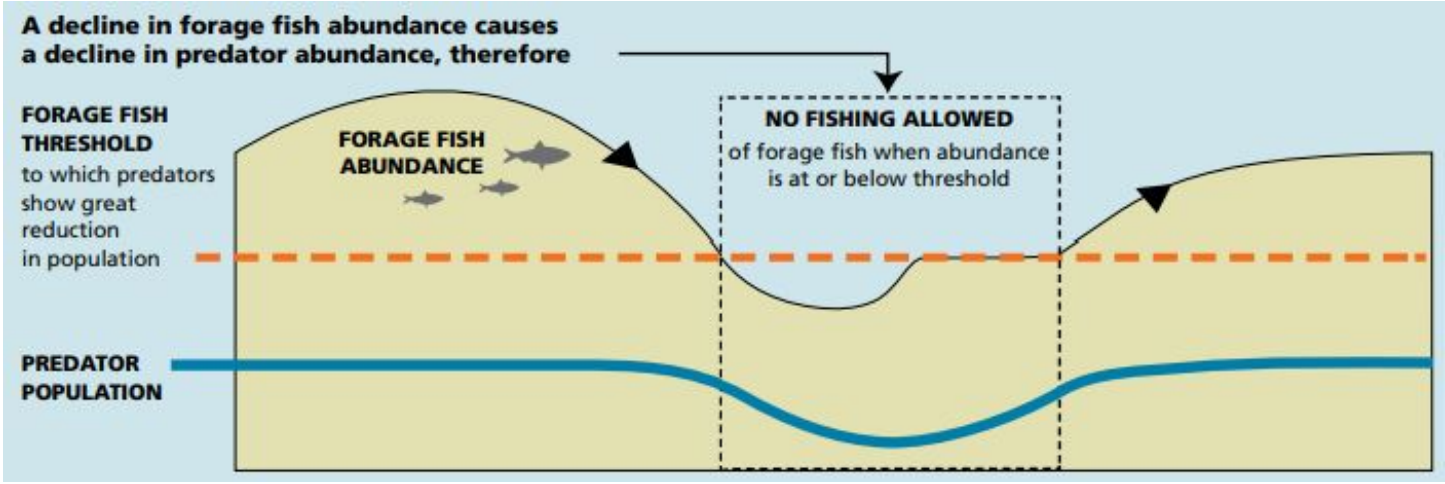




Herring's Role in the Ecosystem

- "Ecosystem overfishing" concerns
  - (Examples: Murawski, 2000; Pikitch et al., 2004; Coll et al., 2008)

- Little Fish, Big Impact - Lenfest Ocean Program, 2012
  - **Forage Fish Control Rule** – apply a "conservation factor" to reduce exploitable yield in accordance with risk tolerance and population levels of predators



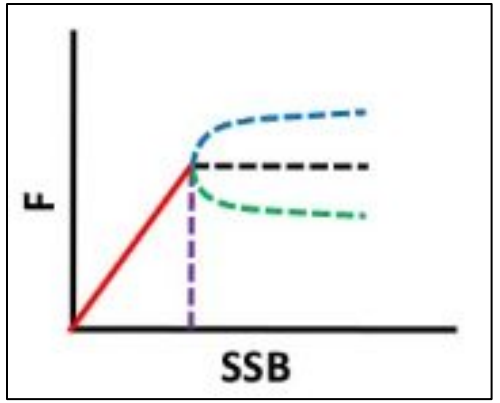
Pikitch et al., 2012

- New England Council initiated Herring Amendment 8 (2016):
  - Propose a long-term harvest control rule for the Atlantic herring fishery that may explicitly account for herring's role in the ecosystem

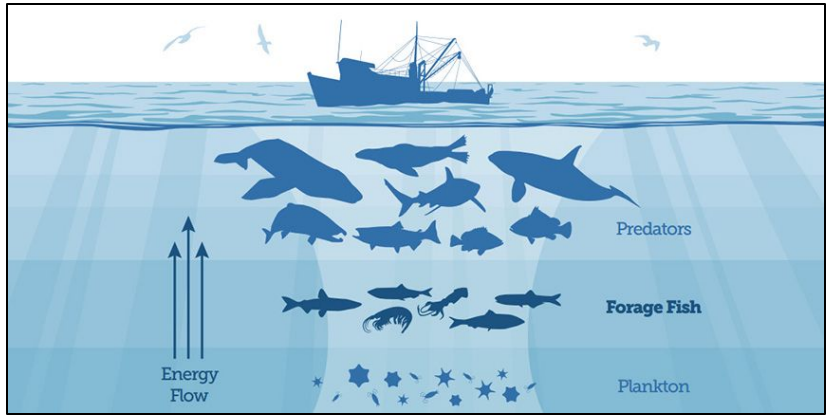
Herring Management Strategy Evaluation

- New England Council held open-invitation, public workshops to identify:

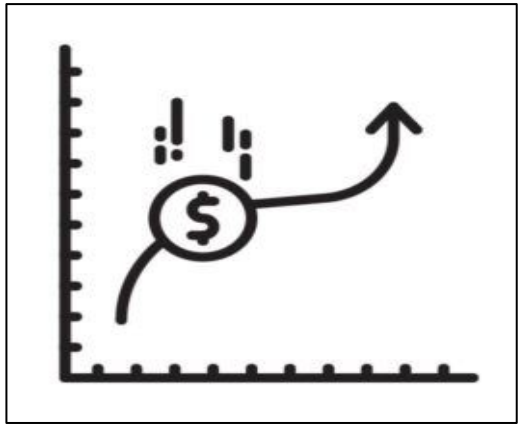
1) Management Strategy
   - ABC Control Rule



2) Operating Model Components
   - Uncertainty in the system - herring
   - Importance of herring as forage
   - Economic objectives

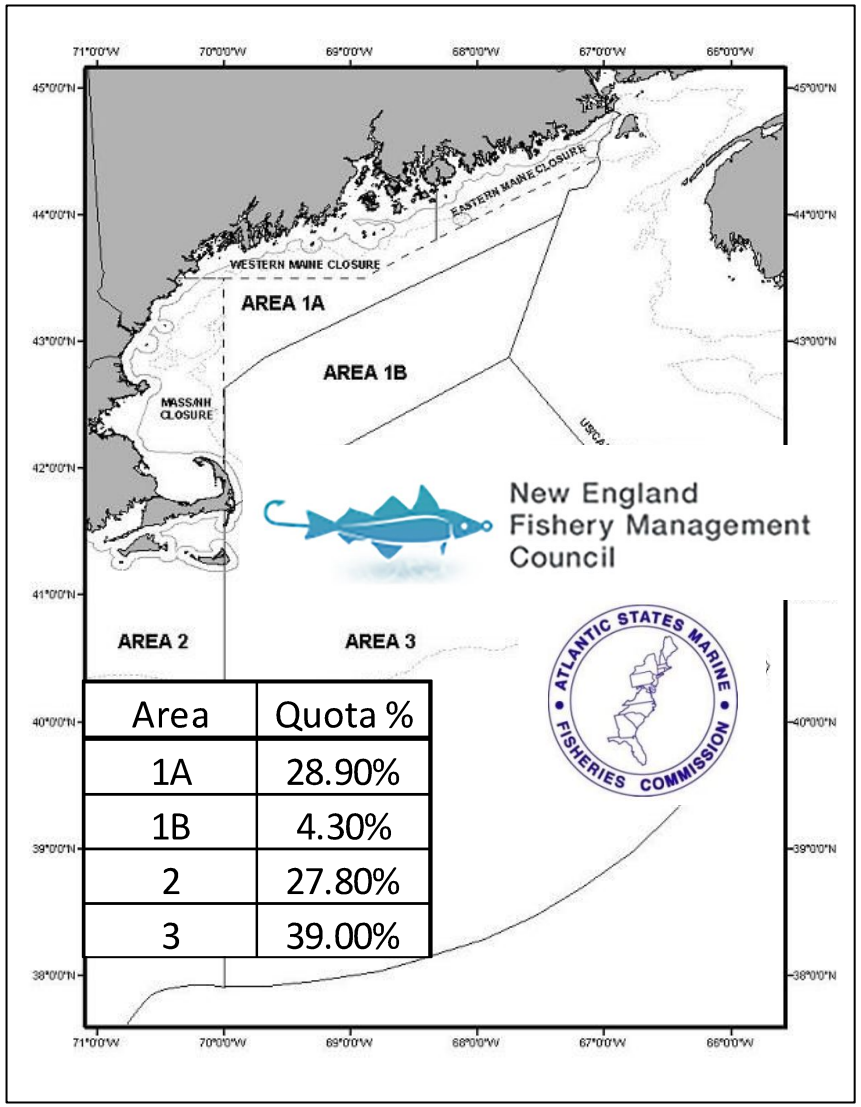


3) Performance Metrics and Fishery Objectives
   - Yield, variation in yield, yield relative to MSY
   - Probability of overfished and overfishing
   - Net revenue
   - Predator productivity, growth, and survival



Atlantic Herring Stakeholders

- 4 management areas with separate quotas
  - Joint Federal and state management
- 2 overlapping commercial gear types
  - Purse seine
  - Mid-water trawl
- Multiple marine interests
  - Directed herring fishery
  - Lobster bait supply
  - Other recreational and commercial fisheries
  - Ecotourism
  - Non-governmental organizations
- MANY interested stakeholders with multiple (conflicting) objectives



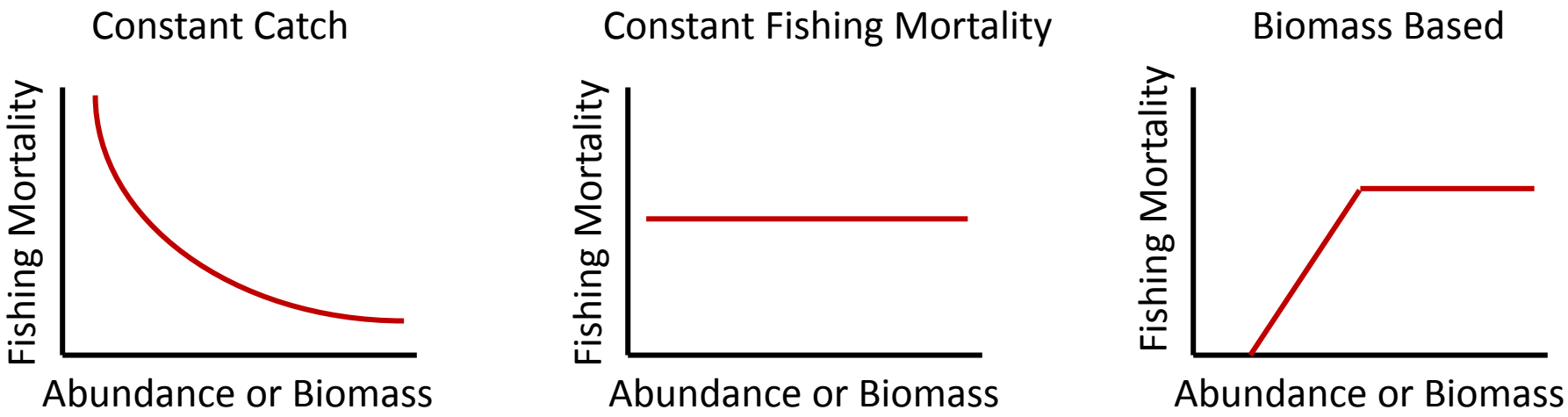
Area	Quota %
1A	28.90%
1B	4.30%
2	27.80%
3	39.00%

Initial Herring Harvest Control Rule Concepts

- Evaluation of various types of control rules and their ability to achieve fishery objectives

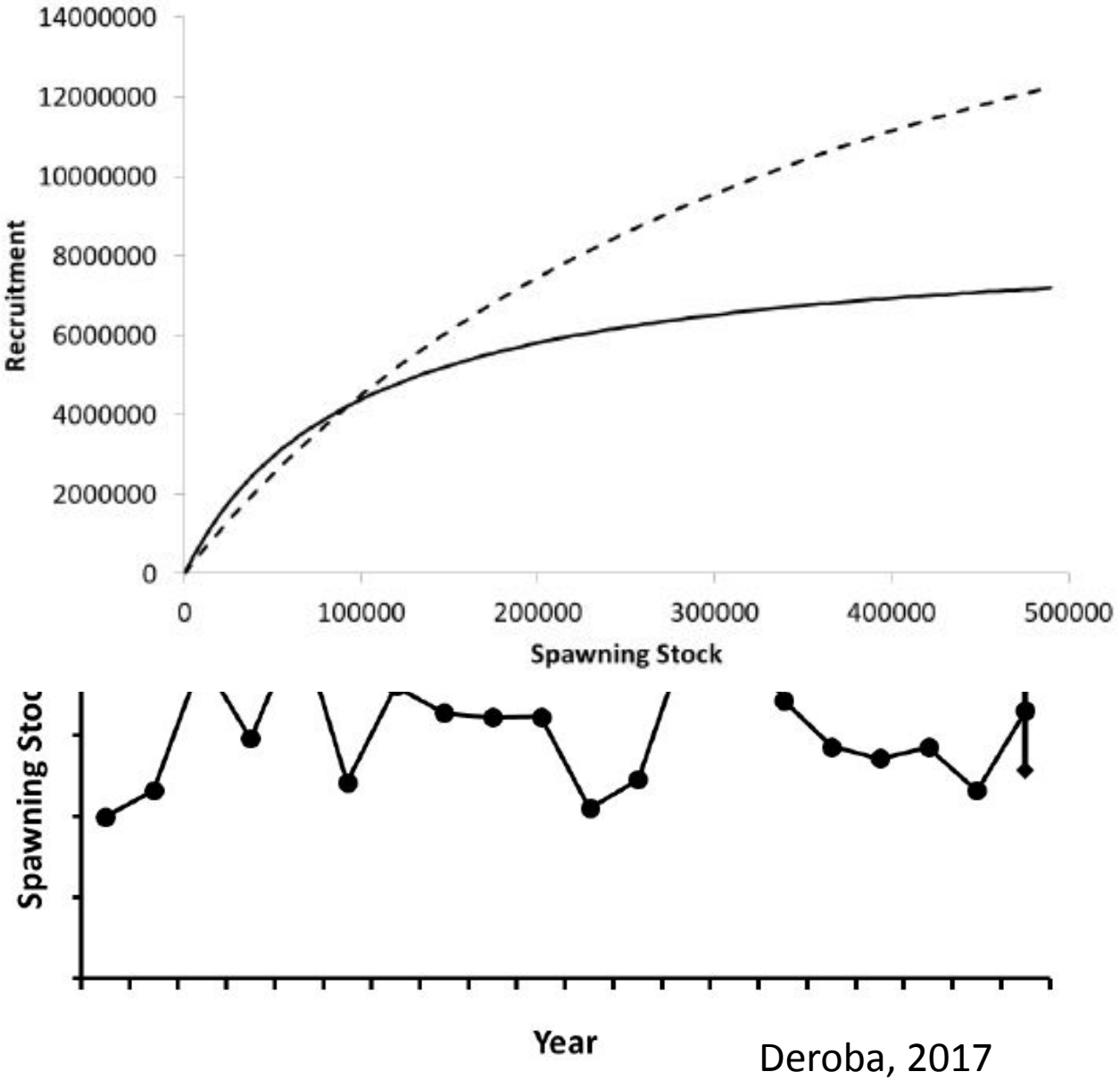
- Constant catch and constant fishing mortality control rules:
  - Did not adequately address goals to maintain viable herring fishery and limit harvest under low stock sizes to explicitly account for herring's role in the ecosystem

- MSE process indicated biomass-based control rule was most suited to the objectives of accounting for herring's role in the ecosystem



Model Components: Herring Uncertainty

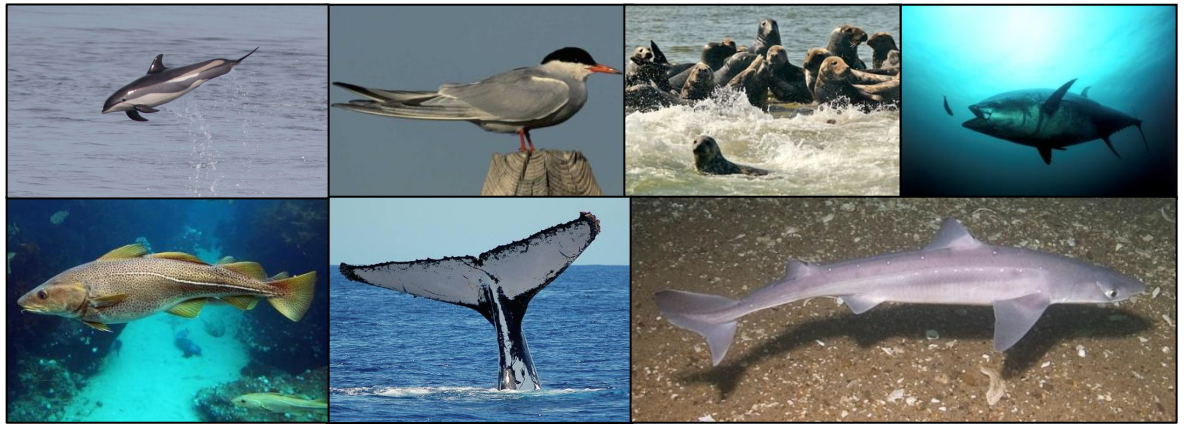
- Single-species operating models
- Herring Production
  - Low recruitment/High M
  - High recruitment/Low M (NEFSC, 2016)
- Herring Growth
  - Good growth
  - Poor growth (NEFSC, 2016)
- Herring Assessment Error
  - Biased (NEFSC, 2016)
  - Unbiased



Deroba, 2017

Model Components: Herring as Forage

- Herring is a high energy prey option for predators in the Northeast affecting:
  - Growth
  - Productivity
  - Survival



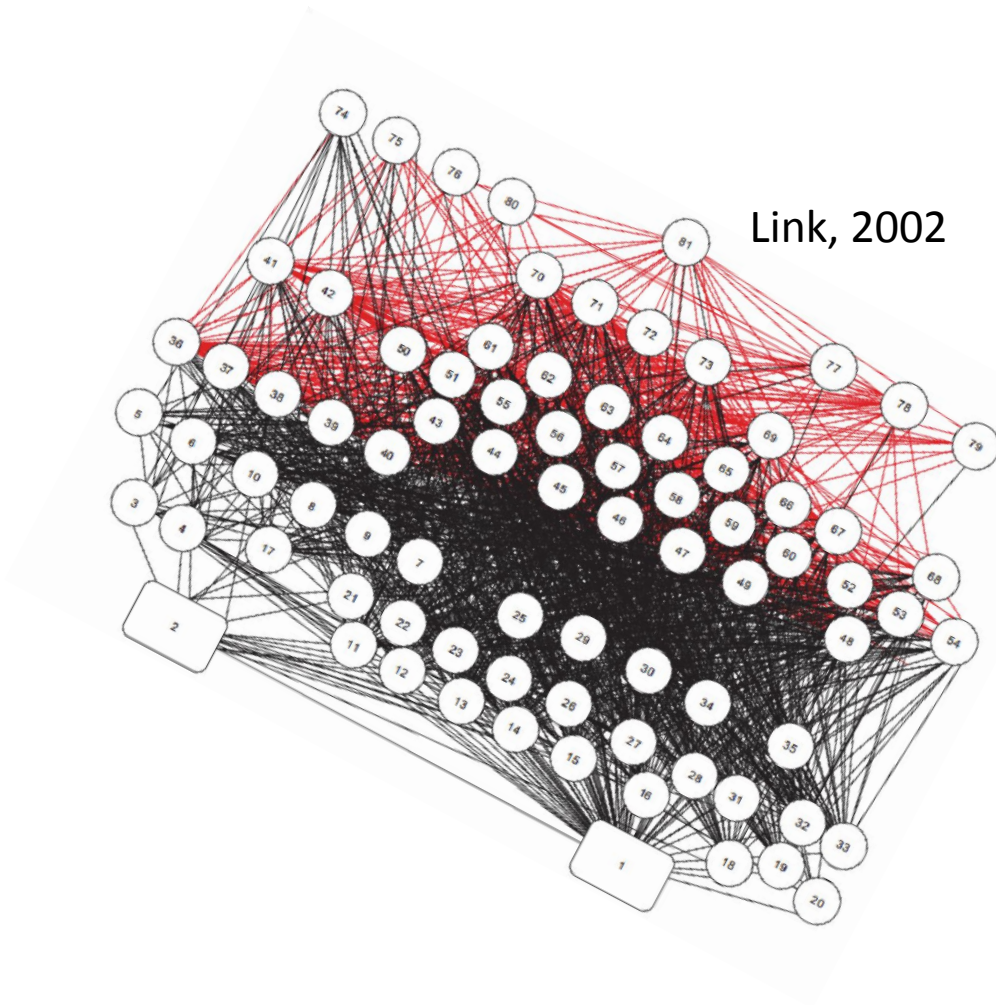
- "General predator" models included:
  - Groundfish (spiny dogfish)
  - Highly migratory species (bluefin tuna)
  - Seabirds (common tern)

- Food web information:
  - Marine mammals (whales)

Predator Class	Consumption of herring	Dependence on herring as prey
Groundfish	Highest	Moderate-low
Marine mammals	Intermediate	Moderate-low
Humans (Fishery)	Intermediate	High
Tuna/billfish	Lowest	High*
Birds	Lowest	Moderate-high

Predator Models

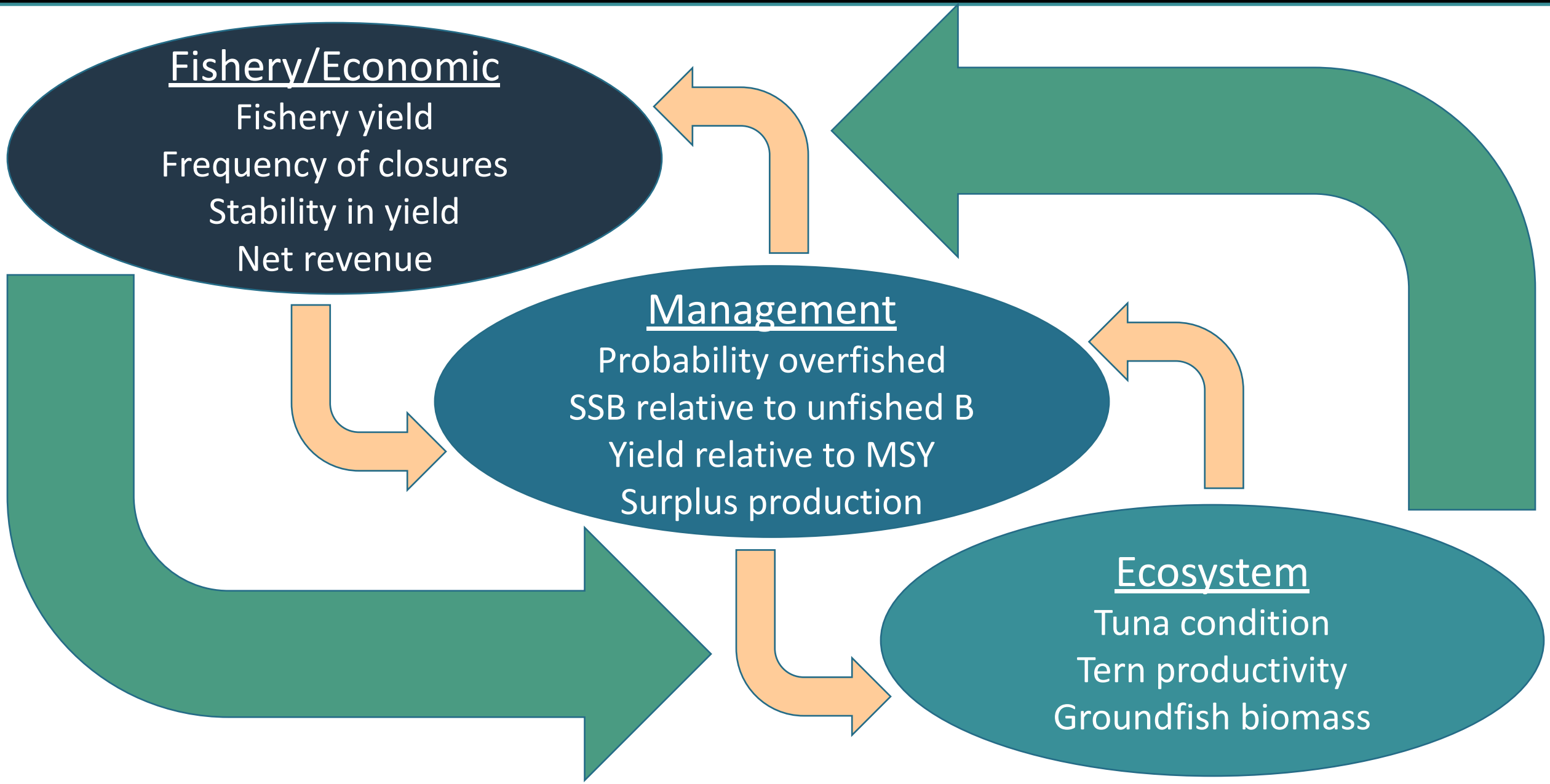
- Delay-difference models that allowed predator processes to be dependent on some aspect of herring population status
- Predator models used output from herring operating models to derive performance metrics
- Deterministic models to evaluate effect of herring management in isolation
- Results:
  - Observed predator responses to herring alone do not dominate dynamics
  - Predator responses to aggregate prey dynamics likely more important than individual prey items
  - Predators have a variety of prey options, and prey condition may be more important than abundance



Link, 2002

Gaichas and Deroba, 2017

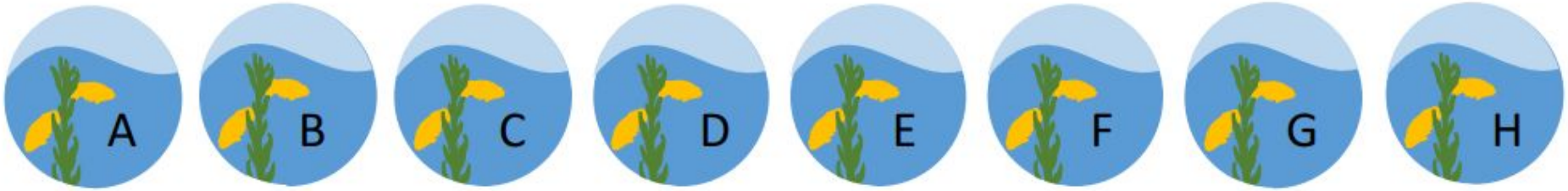
Performance Metrics



Putting it All Together

Over 40,000 outputs from combinations!!!

8 Operating models represent possible states of nature:



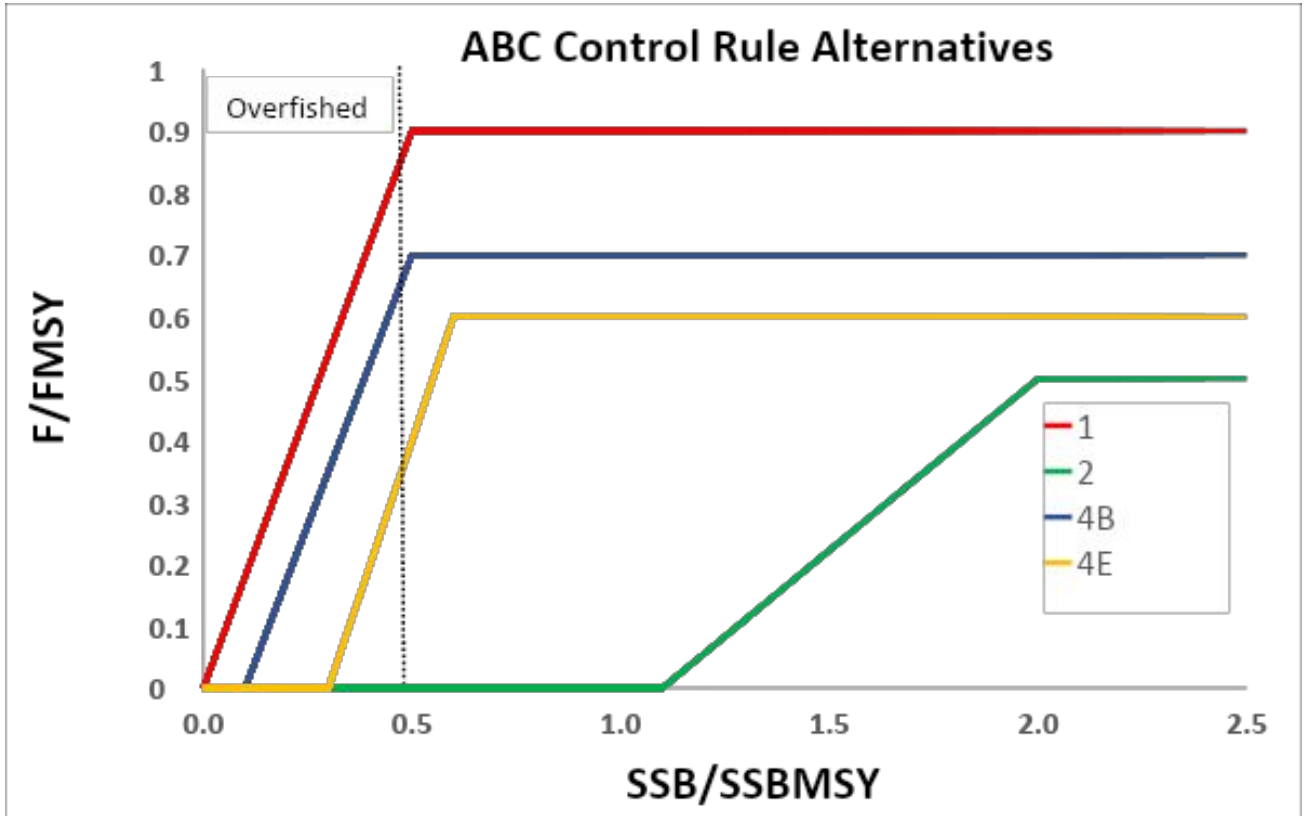
9 Possible control rules:

15 Performance measures of management success reflect objectives:

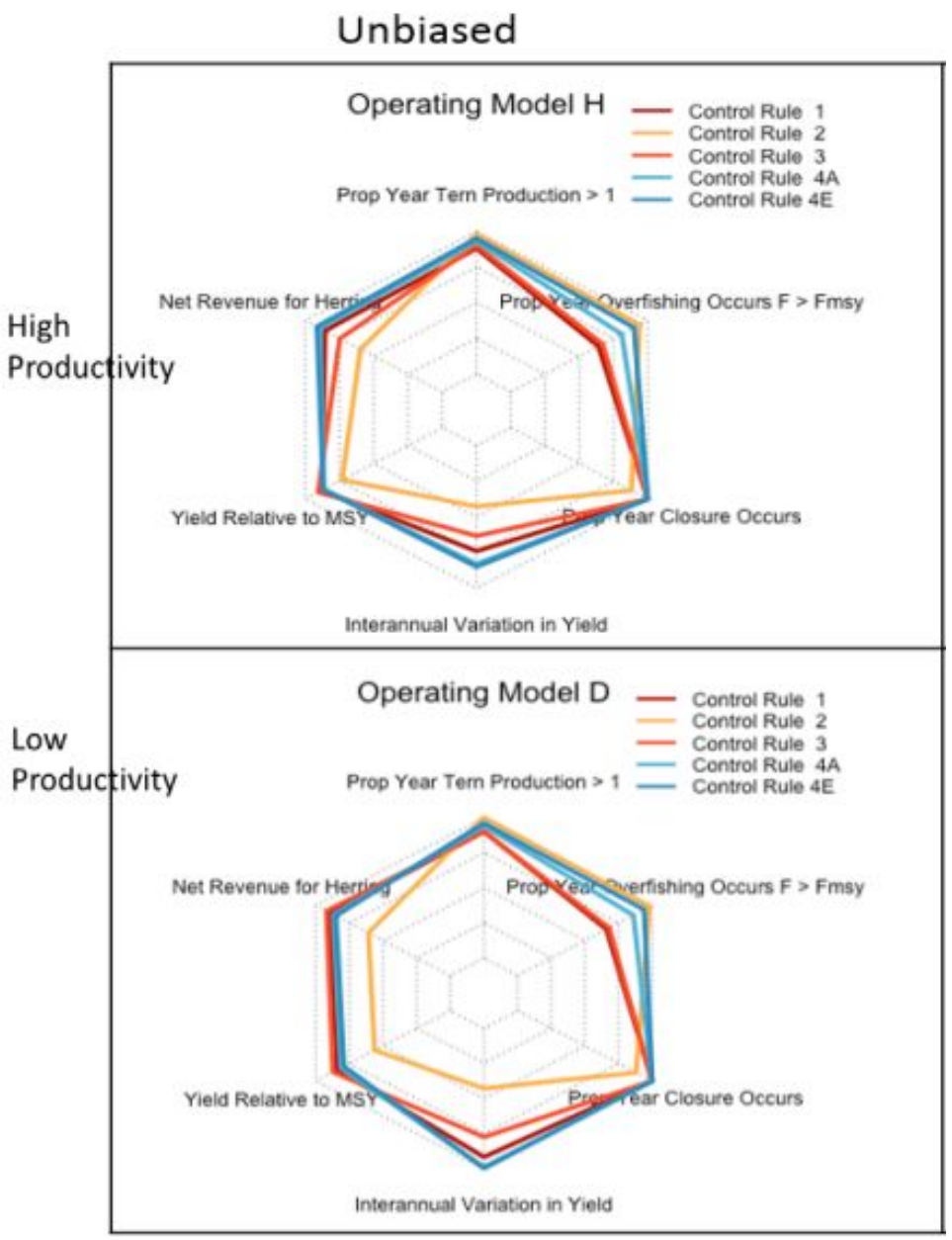
2 Timeframes for control rule implementation:

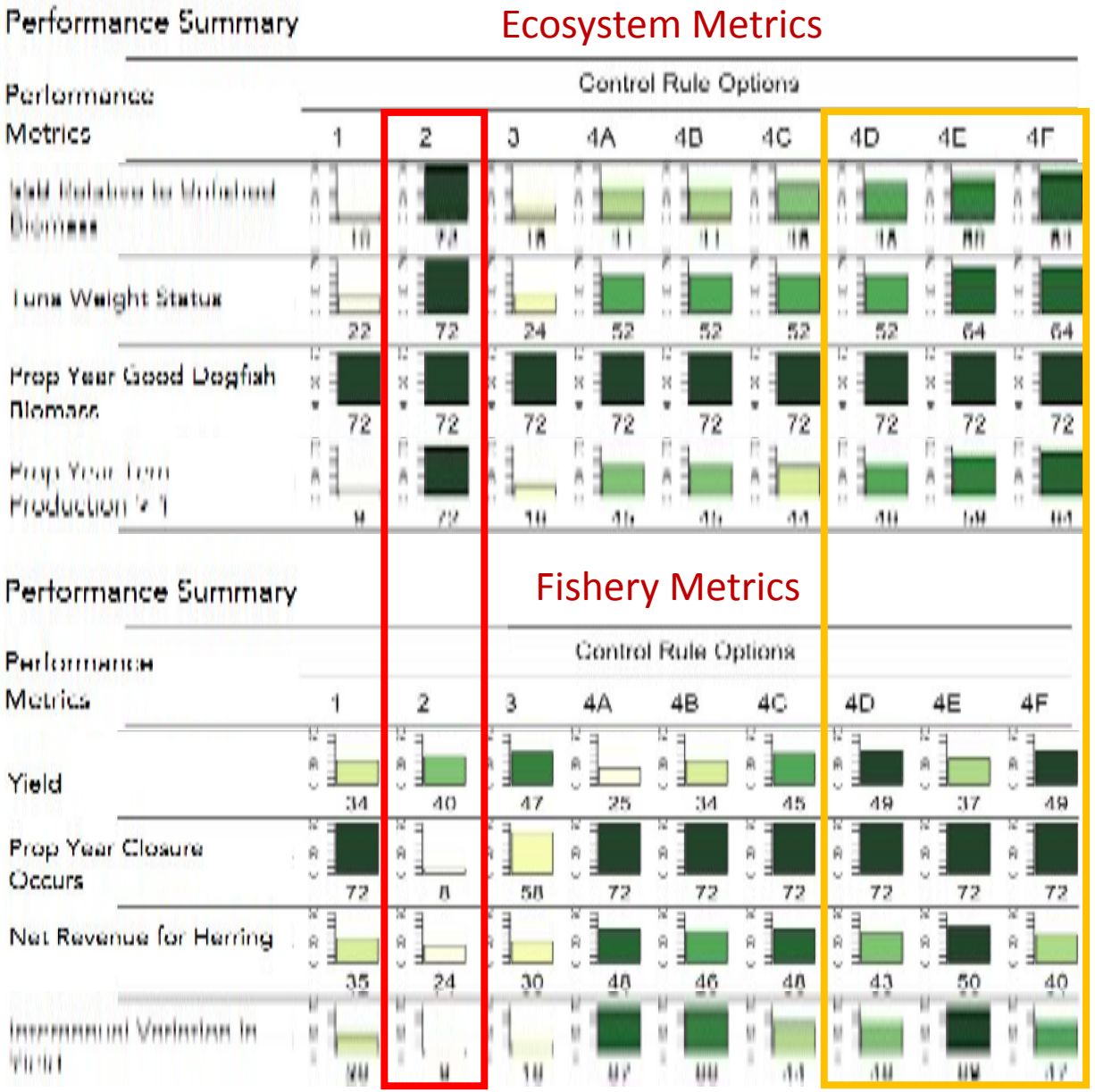
Herring Harvest Control Rule Options

- Option 1:
  - Status Quo
  - Not accounting for ecosystem
- Option 2:
  - Strawman with defined parameters
  - Not meeting fishery objectives
- Option 4:
  - 4B – Lower F target and fishery cutoff
    - Meets more fishery metrics
  - 4E – Lower F target, fishery cutoff, and reduced probability of overfished
    - Meets more ecosystem metrics



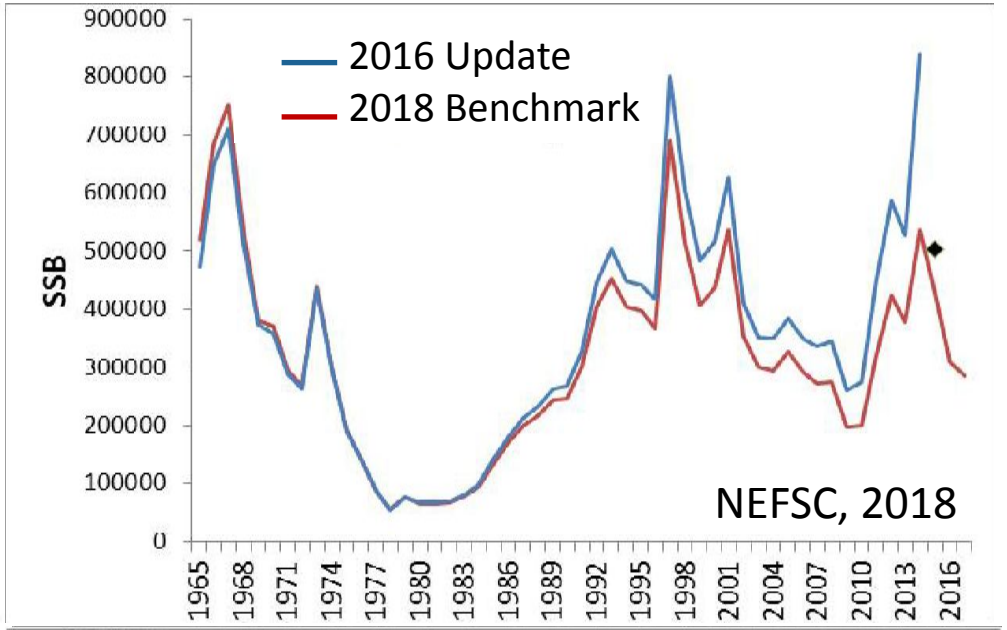
Performance Tradeoffs

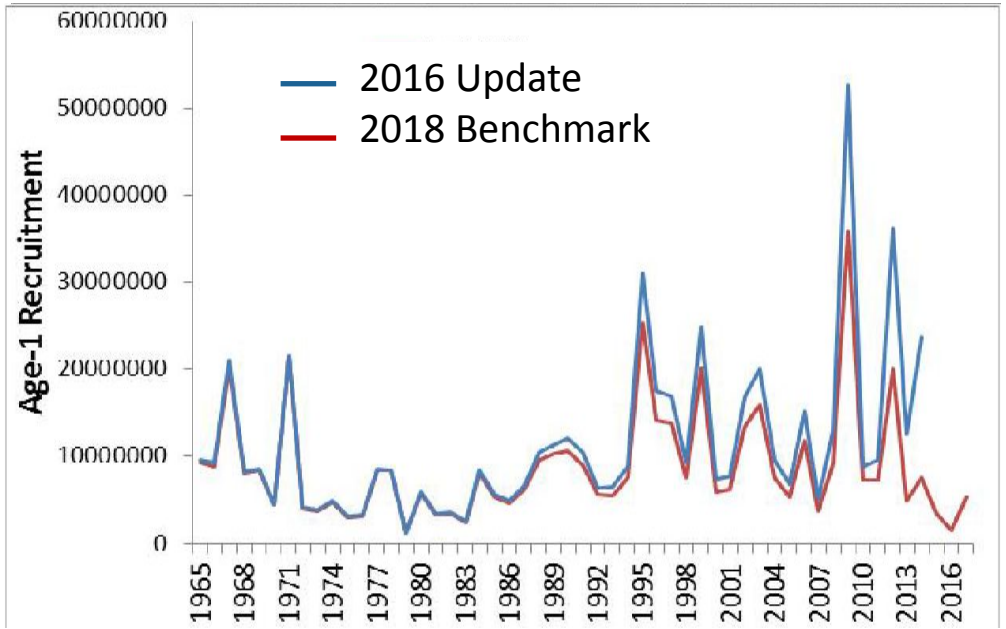




Uh Oh! Major Change in Perception of Stock

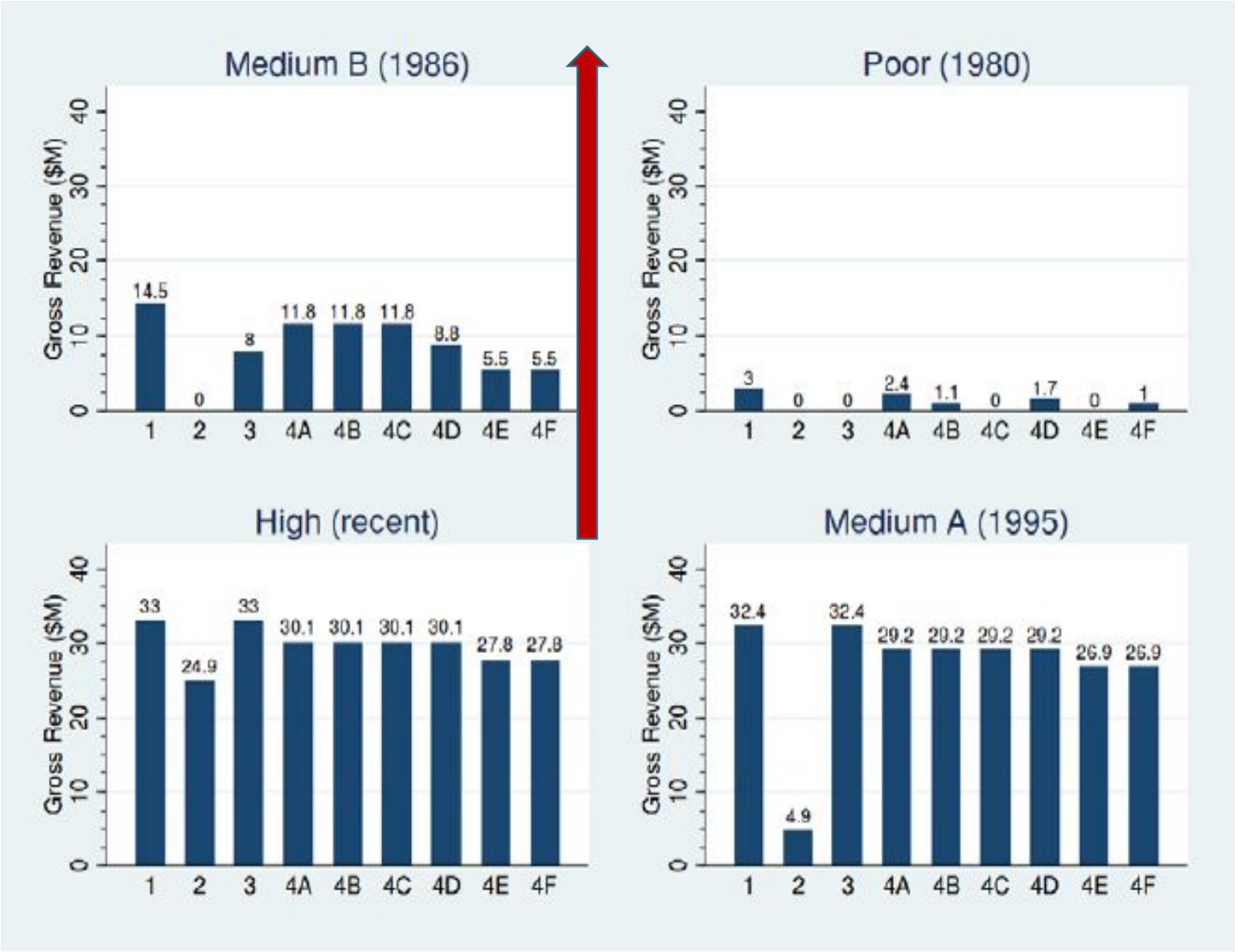
- Herring assessment update in 2016 suggested a high productivity regime (NEFSC, 2016)
- Benchmark assessment in 2018 suggested lower productivity with record low recruitment in the most recent years, but not overfished/no overfishing (NEFSC, 2018)
- Several model adjustments contributed to the change in perception, but a major driver of the difference was the natural mortality (M) assumption
  - 2016: age- and time-varying M
    - Based on predatory consumption estimates to resolve retrospective pattern
  - 2018: age- and time-invariant M = 0.35
    - General agreement between estimates of predatory consumption from stomach contents data





Shifted Focus from Ecosystem to Economics

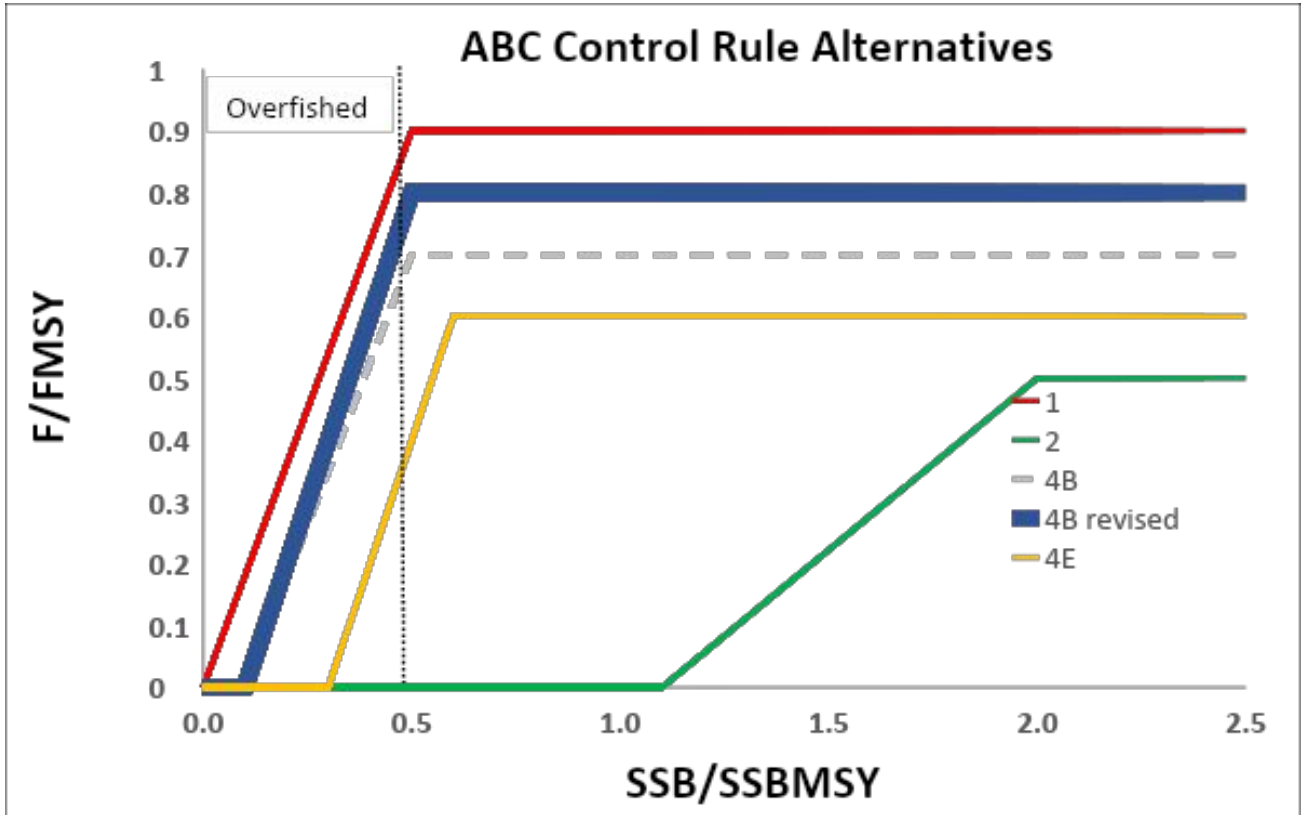
- Change in stock status relative to proposed control rule
- Major economic impacts in short-term
  - 2018 Quota: 111,000mt
  - 2019 Projected Quota under range of harvest control rules:
    - ABC 1: 17,700mt
    - ABC 2: 0mt
    - ABC 4B: 14,500mt
    - ABC 4E: 2,000mt



Revised Harvest Control Rule Option

- Option 4B Revised:
  - Increased F target to 80% F_{MSY}
    - Status quo = 90%
  - Status quo B threshold at 50% SSB_{MSY}
    - Overfished definition
  - Inclusion of a fishery cutoff when SSB is 10% SSB_{MSY}

- Not fully evaluated against performance metrics
  - Council decision to change parameters
  - Combination of other control rules
  - **Unclear how well it accounts for herring's role in the ecosystem**



Lessons Learned

- Refining the scope of stakeholder input may have resulted in more focused options and more time to analyze performance across metrics
  - (Feeney et al., 2019; Deroba et al., 2018)
- Predator-prey dynamics are highly complex and isolating a clear relationship with herring was challenging
  - (Gaichas and Deroba, 2017)
- Changed perception in stock status shifted focus away from long-term ecosystem benefits to short-term economic impacts
- The selected harvest control rule was more “precautionary” than previous measures, but it remains unclear how well it accounts for herring’s role in the ecosystem

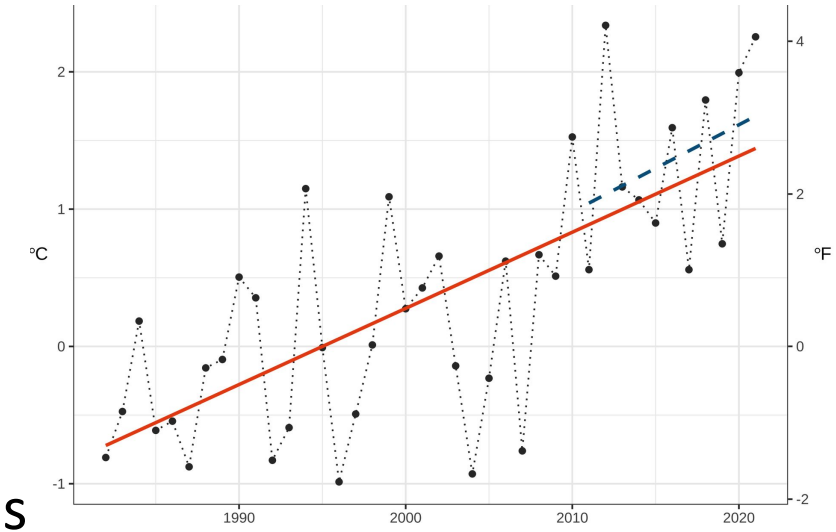
Epilogue

- 2020 assessment update
  - Same model configuration with 2 additional years of data
  - Continued low recruitment
  - Overfished – triggered rebuilding plan

- 2022 assessment update
  - New recruitment assumption based on change point analysis
  - Shortened time series of recruitment to derive SSB_{MSY} (1992 – 2021)
  - SSB_{MSY} reduced from ~270kmt to ~185kmt
  - Still overfished, but rebuilding target more aligned with stock productivity

- NE SSC continued concerns about recruitment and mortality assumptions
  - In an effort to account for herring's role in the ecosystem, we did not explicitly account for the environment's role in herring productivity

Gulf of Maine Summer SST Anomalies



GMRI, 2021